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ANT COLONY WITH COLORED PHEROMONES ROUTING FOR MULTI OBJECTIVES QUALITY OF SERVICES IN WSNs

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Abstract: *In this article, we present a new Ant-routing algorithm with colored pheromones and clustering techniques for satisfying users' Quality of Service (QoS) requirements in Wireless Sensor Networks (WSNs). An important problem is to detect the best route from a source node to the destination node. Moreover, it is considered that the feature of non-uniformly distributed traffic load and possibility existing of the traffic requiring various performances; therefore, it is assumed the different class of traffic required for QoS of communication. In this paper, novel protocol, the suitability of using meta-heuristic an ant colony optimization based on energy saving and multi objectives, the demand of QoS routing protocol for WSN will be very adaptive ,resident power and mainly decrease end-to-end delay. These metrics are used by colored pheromones adapted to the traffic classes. Moreover, we reinforce the proposed method for scalability issue by clustering techniques. We use a proactive route discover algorithms in clusters and reactive discovery mechanism between different clusters. Compared to existing QoS routing protocols, the novel algorithm has been designed for various service categories such as real time (RT) and best effort (BE) traffic, resulted lower packet deadline miss ratio and higher energy efficiency and better QoS and longer lifetime.*

Keywords: *Ant colony optimization, quality of service routing, Wireless sensor network, colored pheromone.*

I. INTRODUCTION

Recent Advances in modern technologies, wireless communications, and digital electronics resulted in the development of multi-functional small size and low-cost sensor nodes (SNs) that form wireless sensor networks (WSNs). These networks can be used in a wide range of application such as, military system, civil domains, medical, industry, and security [1].

Many routing algorithms have been proposed and expanded for WSNs based on a variety of different mechanisms, network architecture, and improvement criteria. Nowadays, routing protocol is mainly concentrated on several routing metrics, for example network lifetime, low delay, etc. Moreover, Efficient-Energy problem is a critical aspect in WSNs implementation. Several techniques have been designed to improve energy efficient algorithms to preserve energy and encourage network for long time to convince the specified QoS requirements of the application [2] [3].

With the rapid growth in potential use of WSNs, a lot of researches had investigated in this field concentrating on providing QoS. On the other hand, nowadays it is possible for sensor units to be designed with multi-functional capabilities, low cost, low power consumption, and small size. Besides, the above mentioned applications of WSNs, for instance biomedical and vehicular have different data traffic with various QoS requirements. Therefore, the role of a QoS routing strategy is to detect short routes that are appropriate for various categorizes of traffic by diverse applications while increasing the utilization of network resources.

Since finding the optimal route is a multi-objective problem with high computational complexity, can be classified as a non-deterministic polynomial (NP) problem. Anyway, heuristics protocols can be appropriate for QoS routing to decrease this complexity. Swarm intelligence systems focus on complex behaviors, typically made up of simple factors that interacting locally with one other and their environment. Swarm intelligence (SI) algorithms are suitable for routing algorithms including Genetic algorithms (GA) [4], Particle swarm optimization (PSO) algorithms [5], and ant colony optimization (ACO) algorithms [6].

The ACO protocol is based on swarm intelligence, which gathers the collective act emerges from the behavior of many simple factors [7]. In ACO, artificial ants detect solutions to concentrate on moving over the shortest route among various routes between their nests to a food source [6]. The first Ant System (AS) [8] used for optimizing problems, for example the Traveling Salesman Problem (TSP) [9] and the

Quadratic Assignment Problem (QAP) [10]. ACO was successfully applied to a noticeable amount of optimization problems. The problem of the preceding methods of ACO routing protocol is that selecting the shortest route was not considered a minimum energy cost route. Previous studious concentrated on reducing the energy consumption by exchanging the hop-count routing with minimum energy routing. These routing protocols calculated a minimum energy route for packet delivery in a multi-hop wireless network.

Considering the dynamic characteristics of routing in WSNs, we have designed algorithm based on multi objectives demand QoS requirements according to the data prototype, which enables to prepare several and customized QoS criterion for each traffic class. The designed protocol an Ant based on multi-objective QoS routing is to calculate by using different colors of pheromone for various categories of traffic. Therefore, the protocol detects network paths guaranteeing a QoS tailored to the special application requirements, which enables better overall network efficiency for a system of applications with heterogeneous QoS requirements.

The rest of the paper is structured around the following sections: a summary of related work is presented in section 2. In section 3, the proposed approach based on ant colony optimization with colored pheromones is presented. Section 4 compares the performance of ACO approach with two popular sensor network routing protocols and demonstrates the increased WSNs lifetime. Conclusion of the work and future directions are provided in the last section.

II. RELATED WORK

With the development in potential use of WSNs to supply the requirements of various applications, a lot of research has been done concentrated on the guarantee of QoS using different protocols. Akkaya and Younis [11] classified routing protocols for WSNs to four groups: QoS aware, data centric, location-based, and hierarchical. QoS-based routing protocols do not prepare any assurance in terms of QoS used in the applications, are classified as best-effort [12].

Preparing QoS assurance in WSNs carries very challenging problems, but some approaches have been offered in the literature for QoS protection. For instance, Sequential Assignment Routing (SAR) [13] is the first routing protocol noticing QoS and energy efficiency for sensor networks. The purpose of the SAR routing protocol is to minimize the average weighted Qos metric throughout the lifetime of the network. Although, the algorithm doses not investigate the reliability and it cannot measure a vast network due to the use of a routing table to compute multiples routes.

The work in SPEED [14] offered a location-based real-time routing protocol and also tried to route packets via paths that guarantee a given fixed speed, and use Exponential Weighted Moving Average to link delay approximation. The purpose of this algorithm is to decrease delay, but it eventually selects the node between the ones assumed to perform the essential speed, which is energy efficient and balances the network load. Moreover, the algorithm doses not consider any guarantee about packet reliability. MMSPEED [15] is developed based on SPEED which is to define multiple delivery speeds for packets with various deadlines to support various QoS. THVR [16] offered real time algorithm as well as on adopted mapping packet deadline to a velocity likes SPEED, which is known as a good metric to delay imposed packet delivery. It takes two hops neighbor information for routing decision. It has performed less end-to-end deadline miss ratio and better energy utilization efficiency to use more neighbor information for routing conclusion in better efficiency.

At present, Swarm Intelligence (SI) has been purposed as a new computational approach that has been replaced to emphasize on control, centralization, and preprogramming, which design features of autonomy, emergence, and distributed functions. Most of the work in this field and still is inspired by collective behaviors observed in natural systems such as insect societies (e.g., ACO), flocks of birds (e.g., PSO), and Schools of fishes [12]. The newly designed solution to QoS routing in WSNs is based on Ant Colony Optimization (ACO) Meta heuristic. ACO routes from the foraging behavior of real ants which leave pheromone while walking in other to mark several desirable routes which should be followed by other member of the colony. It has been observed that the ants in a colony can cover to move in the shortest route among various routes connecting their nest to a food source [6], [7]. As time passes, evaporating pheromone trails make new possibilities, and ants cooperate to select a route with more pheromone intensity. Shorter routes can be more appropriate faster and observed more frequently by the ants. These routes will then absorb more ants, which will in turn enhance the pheromone level, until the full convergence of will be observed in the shortest route.

Zhang et al [17], [18] have researched the use of the AntNet protocol for wired networks and offered a main WSN routing protocol directly derived from AntNet. It is grouped to three different categories including: Sensor-driven cost-aware Ant Routing (SC), Flooded Piggybacked Ant Routing (FP-Ant), Flooded Forward ant routing (FF). ACO-QoSR [19] tries to cope with both strict delay requirements and the limited energy, also calculate resources available at the sensor nodes. This protocol can satisfy the time

limitation of the considered application and has better packet delivery ratio. The Energy Efficient Ant-Based Routing algorithm (EEABR) [20] is proposed to develop network lifetime by decreasing the overhead connection in route detecting. This is accomplished by the energy level of node and transferred distance into the pheromone to update equation of ACO protocol.

Ant Colony [21] is proposed on network lifetime, energy balance, and end to end delay by taking less hop numbers in to attention and selecting the nodes with less pheromone as the next hop. A Self-Optimized multipath routing [22] is centralized on parameters such as delay, energy level, and speed. These parameters are optimally configured and paths are formed for WSNs. However the problem about protocols based on ant colony is that they just applied one color of pheromone. Colored Ant System (CAS) [23] offered "multi-colored pheromones" for solving the subject of coloring and spreading factors to the node clusters. The Multiple Ant Colony Optimizations (MACO) [24] use multiple ant colonies, each attempting to reduce problems and enhance the protocol stability by the consumption of special pheromone colors, however this technique does not imply the traffic classes. Labella and Dressler [25] use colored pheromones to spread the work between the nodes in the sensor/actuator networks (SANET). Moreover Umlauft and Elmenreich [26] proposed a protocol called CPANT, in which the traffic is spread into various categories by using colored pheromones.

In [27], EAQR is an energy-efficient QoS routing protocol for WSNs, and the developed artificial ants bring out various prototypes of pheromones matching to the quality of the route in their return journey, therefore those ants can select their route meets their requirement matching to corresponding pheromones. EAQR supports two prototypes of services, Real Time (RT) and Best Effort (BE), by ant colony with colored pheromones. We applied the basic concept of EAQR and increased it by considering more efficient parameters and a new grading system. AntSensNet [28] is offered a routing algorithm for wireless multimedia sensor networks and satisfied the multi QoS requirements requested by the application. This algorithm made a hierarchical structure on the network before selecting appropriate routes to meet various QoS requirements from various types of traffic resulted in maximizing network utilization, and improving its efficiency. Moreover, by using clustering, it can avoid congestion after quickly judging the average queue length and solve convergence problems, which are typical in ACO. The clustering element uses special factors to guide the selection of CHs in a totally distributed manner. T-ANT is developed by S. Selvakennedy [29], that a cluster-based data gathering protocol for WSNs. The major objective of T-ANT is to optimize network lifetime by forming evenly distributed clusters at minimal energy cost. In comparison with T-ANT, the proposed algorithm clustering process, achieves a permanent CH connection with lower energy costs. Routing comprises both reactive and proactive components. In a reactive path setup aimed at the classes of traffic in the sensor networks, the algorithm can select paths to meet the application QoS requirements, thus improving network performance.

All the algorithms designed do not make a clear differentiation in path choice among traffic by respecting to QoS requirements. Considering just one metric, they determine either the same combined metric or multiple services. According to the traffic type, our basic contribution is propose of a routing algorithm enabling to supply various QoS services on energy, bandwidth, packet delivery ratio, and end-to-end delay all simultaneously.

III. ACO WITH COLORED PHEROMONES

A. Assumptions

The proposed algorithm consists of the local proactive route discovery within a zone of node's neighborhood and reactive communication between the neighborhoods. The network is divided into clusters which are the node's local neighborhood. The size of the zone is not determined locally but by the radius length is measured in hops. Therefore, a routing zone consists of the nodes and all other nodes within the specified radius length. A node may be within multiple overlapping zones and zones could vary in size. The nodes can be categorized as interior and boundary (or peripheral) nodes. Boundary nodes are at a distance from the central node. All other nodes less than the radius are interior nodes. Figure 1 presents overall structure of the proposed method.

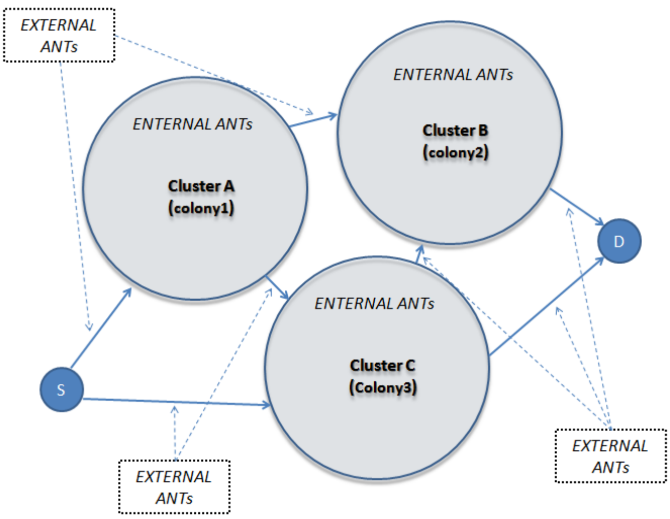

Figure 1: Different type of Ants in the Proposed Scheme

The proposed method discovers all possible paths by forwarding ants and marks them with different backward ants, which have different colored pheromones. We divide Ants to External ants finding paths between different clusters and Internal Ants discovering different paths in clusters. There are different types of nodes in each cluster: cluster head, Border nodes and normal nodes. To restrict the flooding domain of ants, we divide different clusters with individual small colony for each one. Maximum hop count of each internal ant is about two or three hops. In other hand, external ants use directed and restricted flooding to discover a path to destination.

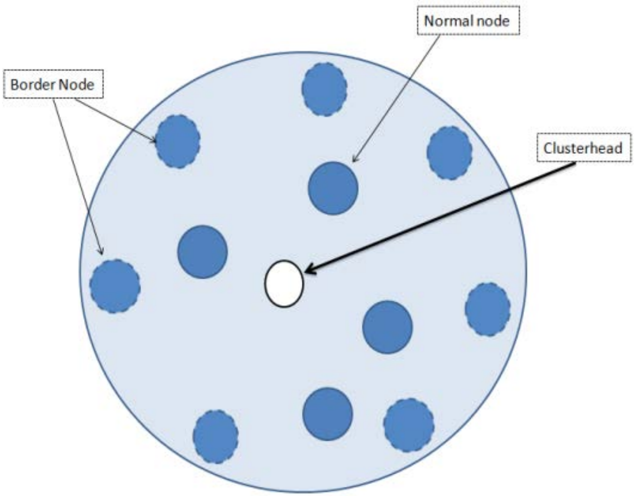

Figure 2: Different Type of Nodes in a Typical Cluster

Each node has two routing tables: Intrazone Routing Table (IntraRT) and Interzone Routing Table (InterRT). The IntraRT is proactively maintained so that a node can obtain a path to any node within its zone quickly. This is done by periodically sending out forward ants to sample path within its zone and determine any topology changes (such as nodes moving away, link failure, new nodes entering the zone, etc.). Once a forward ant reaches a destination, a corresponding backward ant is sent back along the path discovered. The InterRT stores the path to a node beyond its zone. This source routing table is setup on demand as routes outside a zone is required. The peripheral nodes of the zone are used to find routes between zones.

In traditional ant colony system, the value of pheromone to be left depends on the length of route, i.e., the shorter route has the most pheromones than the other routes. The offered method discovers all possible routes by forwarding ants and marking routes for various backward ants, which have various colored pheromones. We use four colors to support four different classes: Real Time, Streaming, Interactive and Best Effort (table1). Each class has various requirements; in table1, critical parameters have been determined.

Table 1: Different Supported Classes in the proposed Method

Class Type	Color of Ant	Description (critical)
Real Time	Red	delay and bandwidth
Streaming	Blue	Bandwidth
Interactive	Green	Delay
Best effort	Black	-

Figure3 presents how one packet arrives and is categorized into various classes. The designed method finds various routes from services with various classes. In servicing to all classes, the offered method tries to provide network resources such as bandwidth, energy and delay.

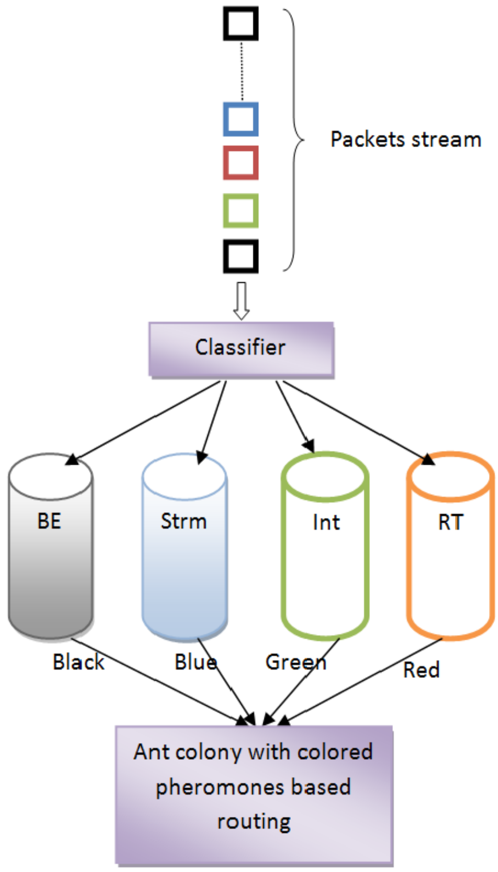

Figure 3: Implementing the Proposed Method in a Typical Wireless Sensor Networks

In the offered method, there are two common phases: detecting all possible routes and coloring them by considering their qualities. *Forward Ant* used to find routes and *Backward Ant* used to sign different routes. Indeed, we have *Backward Ant* with different colors: *Red Backward Ant*, *Blue Backward Ant*, *Green Backward Ant* and *Black Backward Ant*. Source send a *Forward Ant* aggregating different parameters to find routes for arriving to destination. Moreover, destinations send several *Backward Ants* with various colors for different classes. Figure 4 exhibits pseudo code of the offered method phase.

```
Source Node:
------------------
If it is the time then Send FA
If receive a BANT then save route and update tables

Intermediate Node:
--------------------
If receive a FANT then
        Begin
          Compute and update CTP, MRP and MB for FANT
          Forward Ant Base on neighbor's pheromone
        End
If receive a BANT then
        Begin
          Update pheromone table
          Backward Ant Base on its path list
        End

Destination Node:
--------------------
If receive a FANT then
        Begin
          Compute and update CTP, MRP and MB for FANT
          Save this FANT in temp list
          If number of FANTs in temp list is greater than N THEN
            Begin
              Compute parameter of G for all FANT in temp lists by formula (6) with different value of α
              Produce BANTs for N number of FANTs with highest value of GOP in each temp list
            End
        End
```

Figure 4: Pseudo Code of the Proposed Method

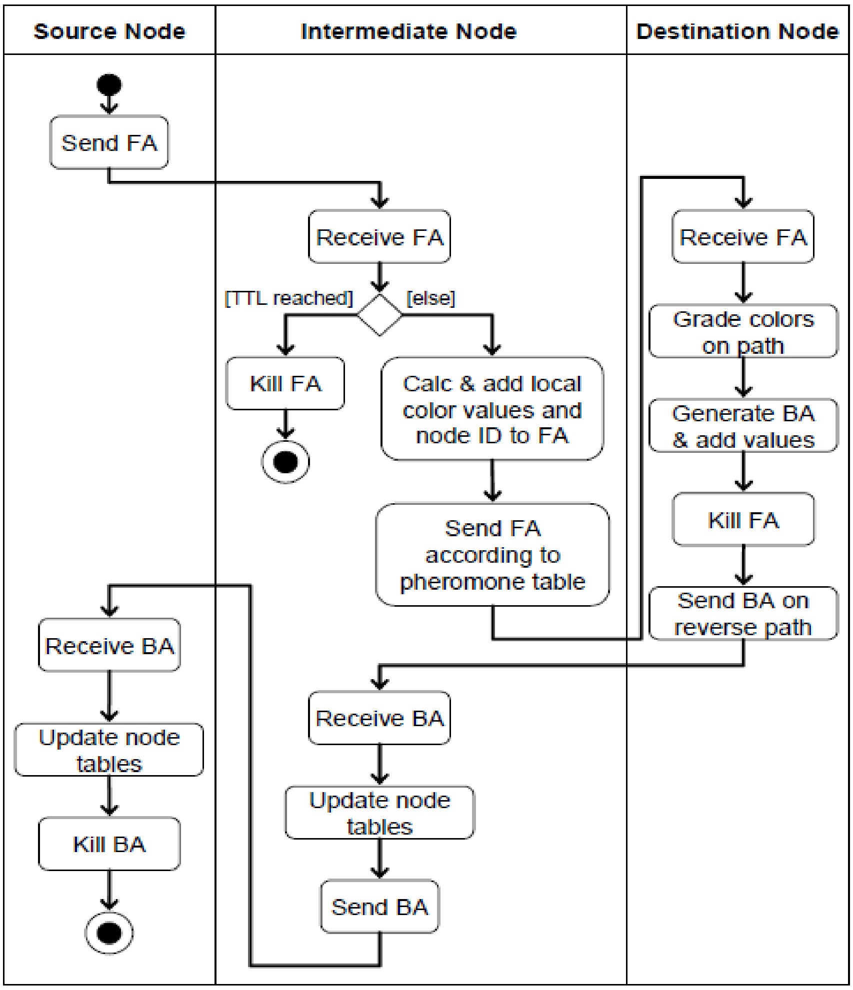

Figure 5: Flowchart of the Proposed Method

Figure 5 presents actions from sending a *Forward Ant* to catch and kill a *Backward Ant*.

Table 2: Different values of α

Service Type	α_1	α_2	α_3	α_4
Real Time	0.45	0.05	0.05	0.45
Streaming	0.2	0.1	0.1	0.6
Interactive	0.65	0.1	0.1	0.15
Best effort	0.05	0.4	0.5	0.05

B. *Forward Ants phase*

In basic ACO based on approach, each ant tries to detect a route providing minimum cost in the network, Ants are launched from a source node and moved towards destination node d, hopping from one node to the next. The minimum cost is calculated according to MRP (Minimum Resident Power), minimum bandwidth, consumed energy to deliver packet to destination, and end-to-end delay.

When a *Forward Ant* arrives in a node, it uses formulas 1, 2 and 4 to calculate various quality parameters. In formula 1 and 2, *Forward Ant* determines minimum level of bottleneck bandwidth and resident power. Formula (3) calculates end-to-end delay by various send/receive time. We determine an efficient parameter called CTP (formula 4 and 5), to calculate how much energy is required to deliver one packet to destination. Formula 5 show relations among transmits power, CTP and receiving power.

$MB = Min\,(BWi)\ \forall\ BWi\ in\ P$ (1)

$MRP = Min(RPi)\ \forall\ RPi\ in\ P$ (2)

ETE= Receive Time – Send Time (3)

$$CTP = \sum_{i-1}^{n} CTPi \quad (4)$$

$P_i = TP_{\,i\text{-}1} - RP_{\,i}$ (5)

C. *Grading various discovered routes*

In formula 6, Grade of Path (GOP) is used to define grade of each route. Such as, Real Time flows, coefficient of end-to-end delay (α1) is the greatest value and after that α2 is the next value. Relation among various values of α is shown in formula7. Different prototypes of flow need different values for α1, α2, α3 and α4.

$$GOF_i = \alpha_1\left|\frac{ETEi}{MAX\_ETE}\right| + \alpha_2\left|\frac{MRPi}{MAX\_MRP}\right| + \alpha_3\left|\frac{CTPi}{MAX\_CTP}\right| + \alpha_4\left|\frac{MBi}{MAX\_MB}\right| \quad (6)$$

$$\alpha 1 + \alpha 2 + \alpha 3 + \alpha 4 = 1 \quad (7)$$

In table 2, we use the various values calculated based on the simulation experiences. Four types of flows discuss their needs in calculating GOP.

Figure 6 presents Forward Ant in destination node. It shows how different color of Backward Ant is launched and grading is done. The process of the best route choice shows Real time with Red Backward Ant, Streaming with Blue Backward Ant, Interactive with Green Backward Ant and Best Effort with Black Backward Ant, respectively.

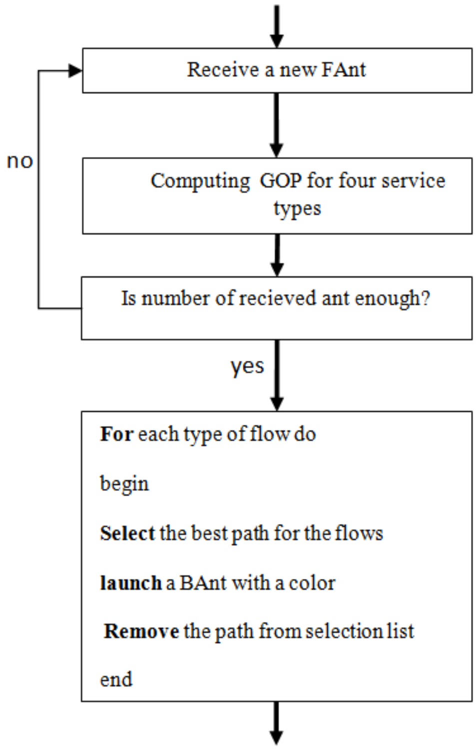

Figure 6: Flowchart of grading of discovered path

D. Routing table update

Each Backward Ant updates routing table of intermediate node according to GOP of the chosen route. It means better routes have stronger pheromones; then they would be chosen with more probability to forward packets. Formula 8 presents how a kind of pheromone is updated via a Backward Ant.

$P_n^d = P_n^d + \Delta * \text{GOP}$ (8)

Each node periodically updates path table by neighbor nodes. It sends value of various prototypes of pheromones and updates path table by formula 9. In formula 9, CW is Color Weight, which can be Blue Weight, Green Weight, Black Weight and MCW is Maximum CW. Indeed, Grade of Node (GON) defines how much a node is good based on value of various pheromones. GON is calculated for various colors.

$GON_{\,i} = CW_i\ /\ MCW$ (9)

To calculate probability of selecting one neighbor node, formula 10 is used. It is defined for each flow,

probability of selection. In formula 10, n is number of neighbors.

$$\Pr ob_i = \frac{GONi}{\sum_{j=1}^{n} GON\ j} \quad (10)$$

IV. PERFORMANCE EVALUATION

The simulation code and scenario of this research was implemented within Global Mobile Simulation (GloMoSim) library [30].The GloMoSim is a scalable simulation environment for wireless network systems by using parallel discrete-event simulation capability provided by PARSEC [10]. This simulation study modeled a network of mobile nodes (100 nodes to 500 nodes) placed randomly within an area of 1000×1000m2. Radio propagation of each node was set to about 250 meters and channel capacity was 2 Mbit/sec. Each simulation is executed for 300 seconds of simulation time. The IEEE 802.11 Distributed Coordination function was used as the medium access control. The mobility model is Random-Way point where nodes randomly selected the moving direction, and when they reached the simulation terrain boundary, they bounced back and continued to move. The Constant Bit Rate (CBR) was selected as the traffic since the GloMoSim does not support Variable Bit Rate (VBR) traffic. The size of data payload was 512 bytes. To evaluate the proposed method, it is compared with two novel methods which recently proposed: EAQR and AntSensNet.

In the first scenario, results have been shown with increase of number node from 100 to 500. Results for different flows are presented in one chart. They present that overall performance of our proposed method completely come over EAQR and AntSensNet. AntSensNet consider four different issues in routing process. Thus it has higher delay than EAQR. In other hand, the proposed method considers efficient parameters e.g. Bandwidth in routing process. This efficiency leads to higher rate of packet delivery.

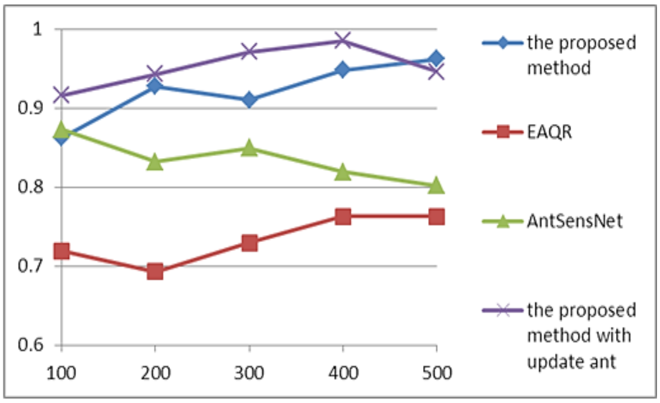

Figure 7: Packet delivery ratio as function of number nodes

Figure 7 presents number of delivered packets in the proposed method is very higher than EAQR. Figure 8 shows end to end delay for two simulated method. The proposed method uses high efficient heuristic mechanism to decrease overall ETE delay.

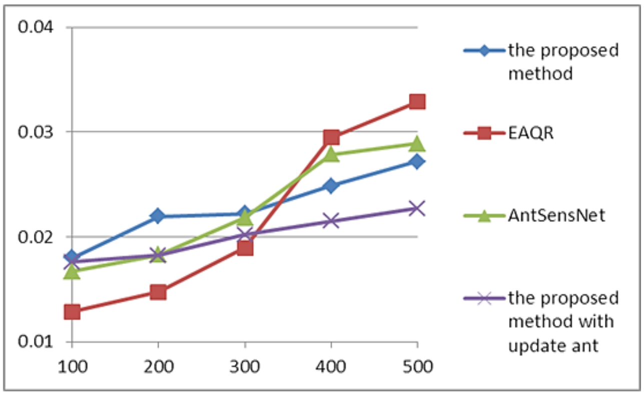

Figure 8: End to end delay as function of number nodes

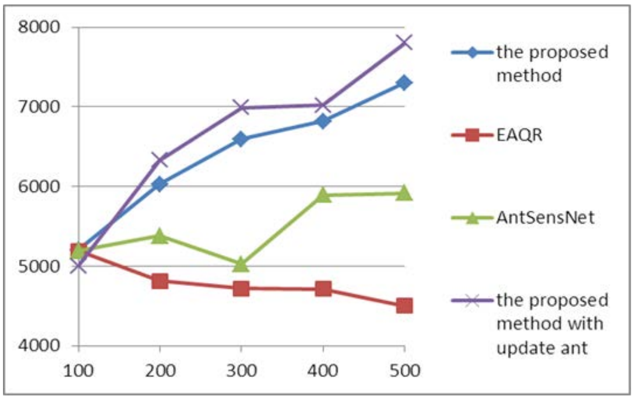

Figure9: Throughput as function of number nodes

Figure 10 clarifies another aspect of the proposed method. It presents that the proposed method uses minimum number of overhead packets to handle packets to destination nodes.

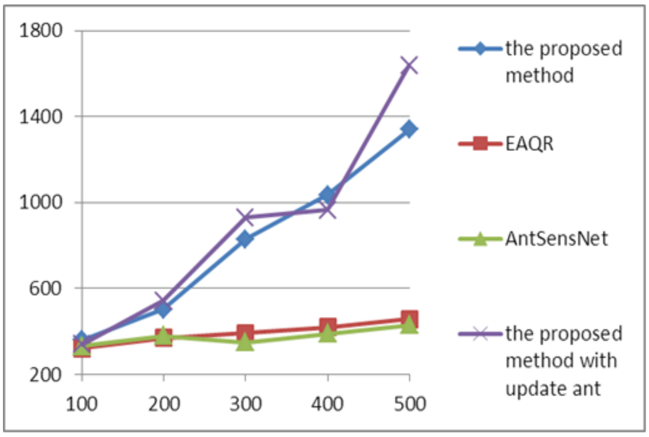

Figure 10: Life time as function of number nodes

In the second experiment, with large area (2000*2000 m2), more nodes (200 nodes) are done to verify to optimize the result of service quality metrics in a relatively border WSNs environment. In table3, we present details of performance evaluation for four prototypes of services. Normalized control is calculated from dividing whole control packets by the number of received data packets. The proposed method tries to balance power consumption in

throughout of network with considering power level of intermediate node as a main issue in routing process. Regarding to the synthetic QoS resulted in the rising lifetime and throughput.

Table 3: Detail of Results for Four Types of Services

	Proposed method				Proposed method with Update Ant				AntSensNet				EAQR	
	Service1	Service2	Service3	Service4	Service1	Service2	Service3	Service4	Servic1	Service2	Service3	Service4	Service1, 2,3	Service4
Average ETE Delay(ms)	13	189	46	452	15	112	41	329	23	217	128	319	75	371
Packet Delivery Ratio (%)	95%	79%	86%	81%	97%	85%	86%	89%	84%	66%	67%	88%	81%	52%
Throughput(bit/sec)	3014	2978	1986	2417	3005	3140	2239	2891	2134	1786	1502	2871	2809	2067
Lifetime(sec)	417				401				386				319	
Total Control Packets	17802				18994				18892				19273	
Normalized Control Packets	0.034				0.031				0.066				0.087	

V. CONCLUSION

In this article, we have offered a novel Ant-routing protocol for WSNs. The offered algorithm takes in to account the traffic diversity, which is typical for many applications, and it provides a different routing using various QoS metrics. Data traffic has been classified into several categories according to the required QoS. This supports traffic classes with orthogonal requirements by using colored pheromones. Color is used to mark various trails appropriate to the different traffic classes. Colored pheromones, instead of a signal goodness criterion, considerer various criteria and the data are transmitted according to the color of the pheromone in the concerned route. Moreover, adding of third factor (updating ants of the neighboring nodes) increases the cooperation between the nodes and decreases delay rate in data transmission. Simulation result show that the performance of proposed algorithm outperforms the EAQR and AntSensNet in terms of packet delivery ratio, end- to –end delay and throughput and lifetime. The obtained conclusions are very encouraging and display that the algorithm ensures well QoS and makes traffic differentiation based on QoS requirements.

In future work, the offered routing protocol needs to be improved effectively for nodes with high mobility by setting some appropriate WSNs parameters, routing network with multiple sink nodes, and topology changes in such energy constrained environment. Besides, we are going to examine our work over real traffic sessions and evaluate its performance with various scenarios.

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